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(54) RAMP-SHAPED INTERVERTEBRAL IMPLANT

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(52) **U.S. Cl.** **623/17.16**; 623/17.11; 623/16.11
(58) **Field of Search** 623/16.11, 23.51, 623/23.61, 17.11, 17.16; 606/60, 61

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,349,921	9/1982	Kuntz .
4,714,469	12/1987	Kenna .
4,863,477	9/1989	Monson .
4,932,973 *	6/1990	Gendler 623/23.63
5,047,058	9/1991	Roberts et al. .
5,306,307	4/1994	Senter et al. .
5,306,309	4/1994	Wagner et al. .
5,314,478	5/1994	Oka et al. .
5,425,772	6/1995	Brantigan .
5,425,773	6/1995	Boyd et al. .
5,443,514	8/1995	Steffee .
5,458,638	10/1995	Kuslich et al. .
5,458,643	10/1995	Oka et al. .
5,489,308	2/1996	Kuslich et al. .
5,514,180	5/1996	Michelson .
5,522,899	6/1996	Heggeness et al. .
5,534,028	7/1996	Bao et al. .
5,534,030	7/1996	Navarro et al. .
5,554,191	9/1996	Lahille et al. .
5,562,738	10/1996	Boyd et al. .
5,571,190	11/1996	Ulrich et al. .
5,591,235	1/1997	Kuslich .
5,607,424	3/1997	Tropiano .
5,645,596	7/1997	Kim et al. .
5,645,598	7/1997	Brosnahan, III .
5,653,761	8/1997	Pisharodi .
5,653,762	8/1997	Pisharodi et al. .
5,658,336	8/1997	Pisharodi .
5,658,337	8/1997	Kohrs et al. .
5,669,909	9/1997	Zdeblick et al. .
5,683,463	11/1997	Godefroy et al. .
5,683,464	11/1997	Wagner et al. .
5,716,415	2/1998	Steffee .
5,728,159	3/1998	Stroever et al. .
5,766,251	6/1998	Koshino .
5,766,252	6/1998	Henry et al. .

(List continued on next page.)

OTHER PUBLICATIONS

Vich, Jose M. Otero, Anterior Cervical Interbody Fusion With Threaded Cylindrical Bone, 1985, J. Neurosurg., vol. 63, pp. 750–753.

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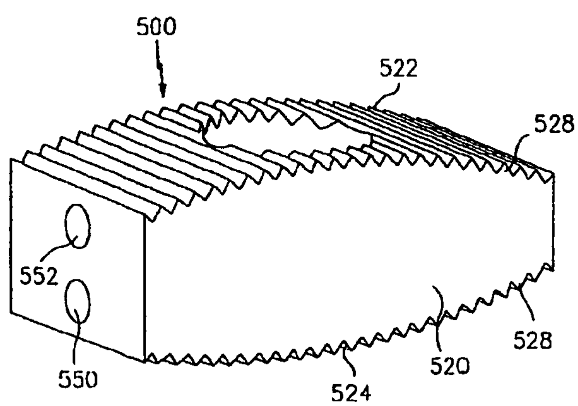
(57) **ABSTRACT**

A ramp-shaped intervertebral implant is disclosed. The implant has a body having a first end, a second end, a top surface and a bottom surface. At least one of the top and bottom surfaces is tapered and converges towards the second end of the body. An opening extends through the body and has one end opening onto the top surface of the implant and the other end opening onto the bottom surface of the implant. The implant can be formed from the diaphysis or metaphysis of a long bone, wherein the intramedullary canal of the long bone defines the opening. Alternately, the implant can be made from any biocompatible material having the requisite strength requirement.

19 Claims, 6 Drawing Sheets



U.S. PATENT DOCUMENTS

5,769,897	6/1998	Härle .
5,776,199	7/1998	Michelson .
5,782,919	7/1998	Zdeblick et al. .
5,785,710	7/1998	Michelson .
5,865,845	2/1999	Thalgott .
5,888,227	3/1999	Cottle .
5,895,428	4/1999	Berry .
5,904,719	5/1999	Errico et al. .

* cited by examiner

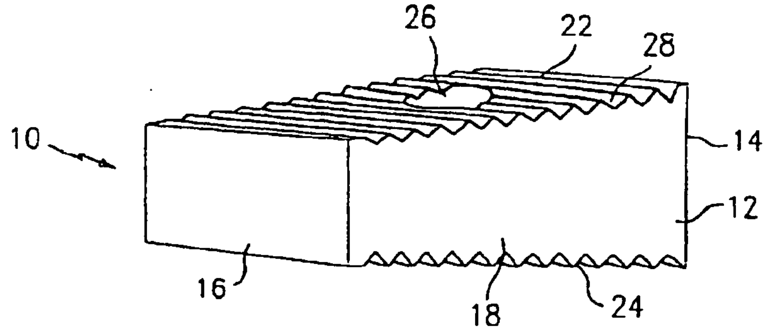


FIG. 1

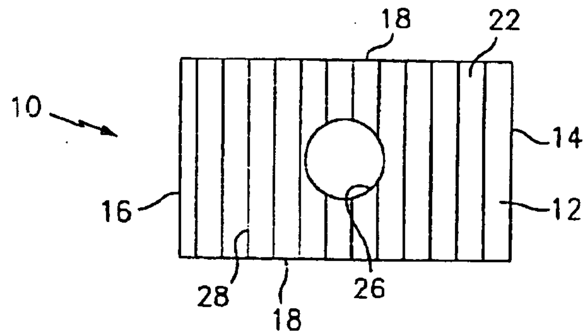


FIG. 2

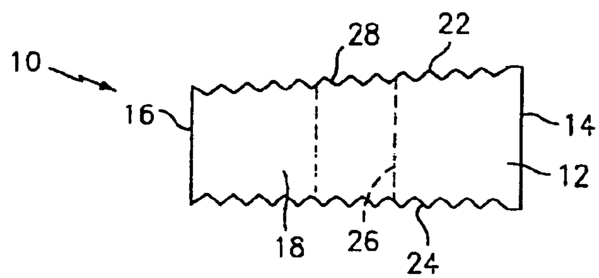


FIG. 3

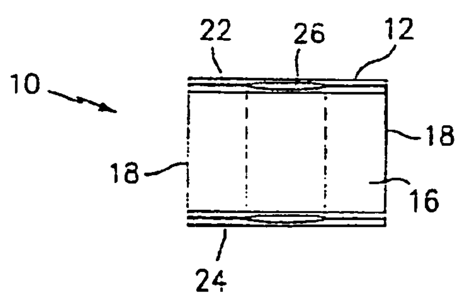


FIG. 4

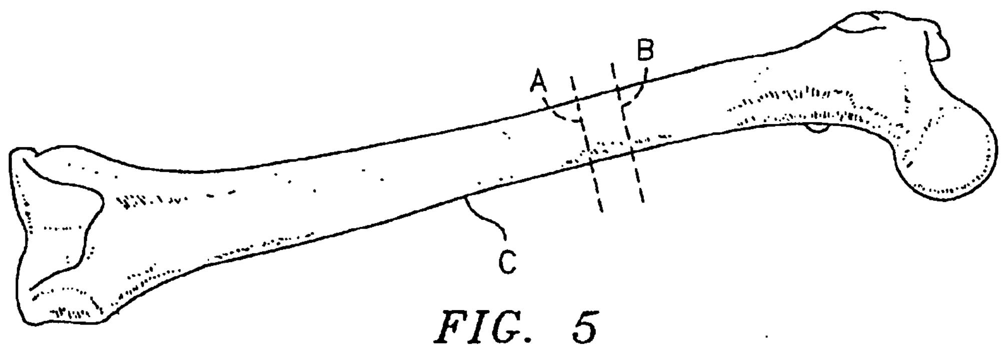


FIG. 5

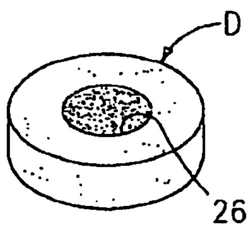


FIG. 6

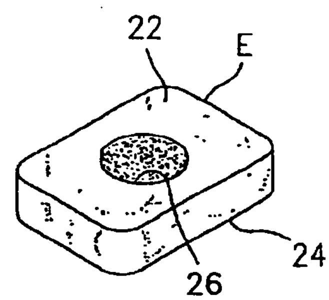


FIG. 7

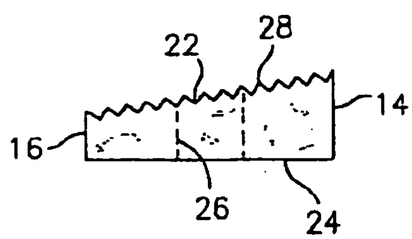


FIG. 8

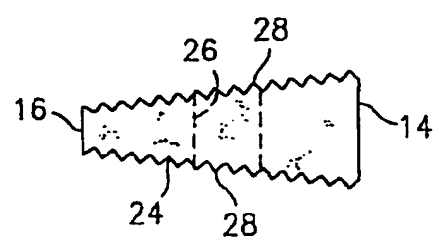


FIG. 9

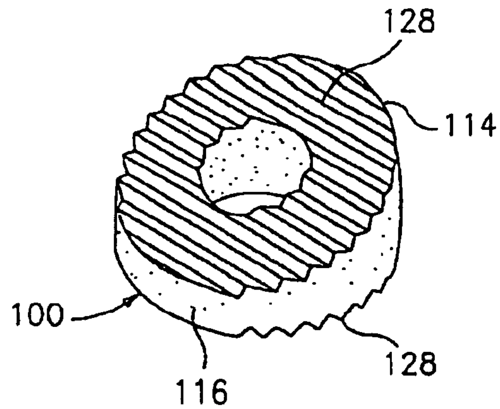


FIG. 10

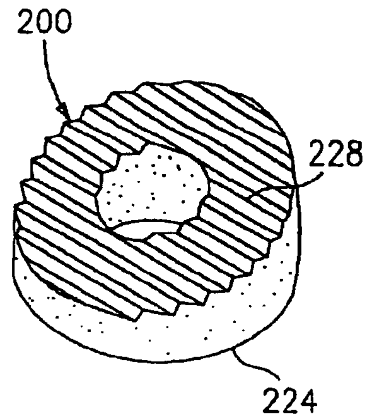


FIG. 11

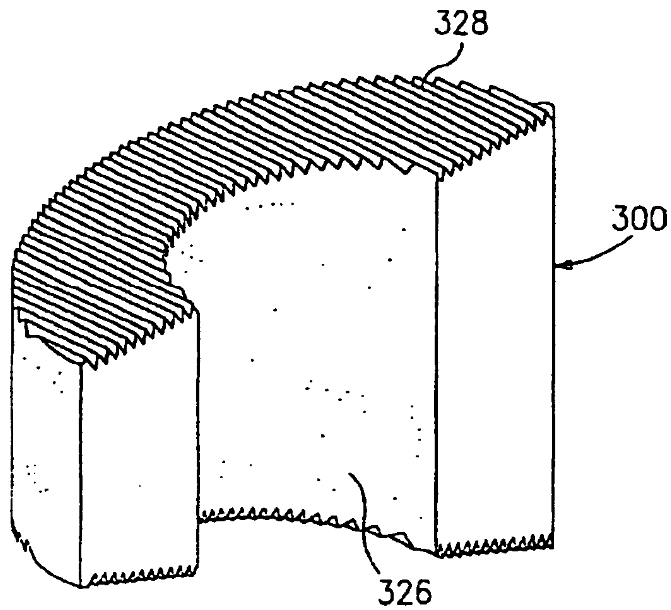


FIG. 12

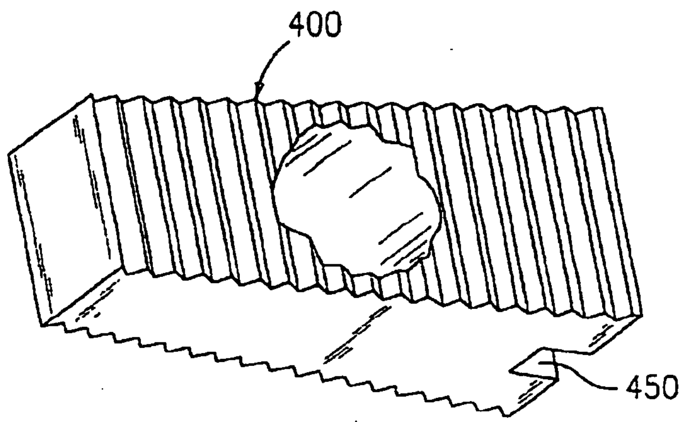


FIG. 13

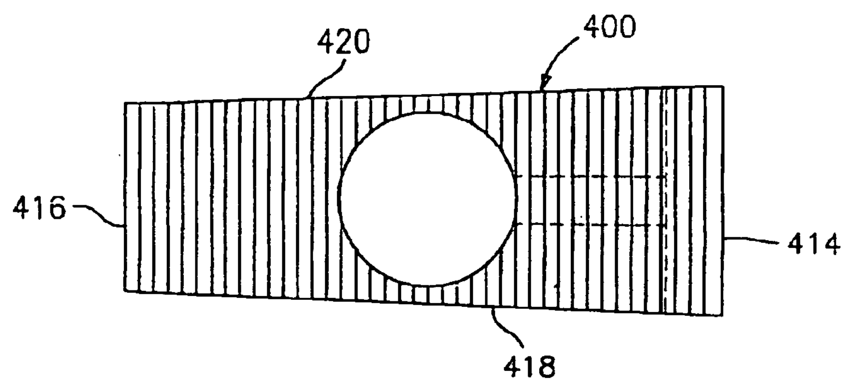


FIG. 14

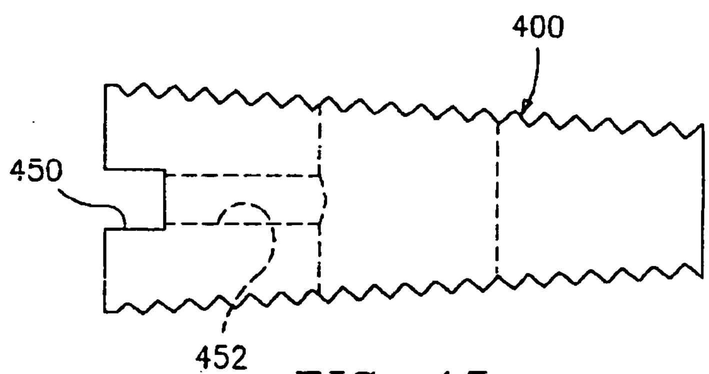


FIG. 15

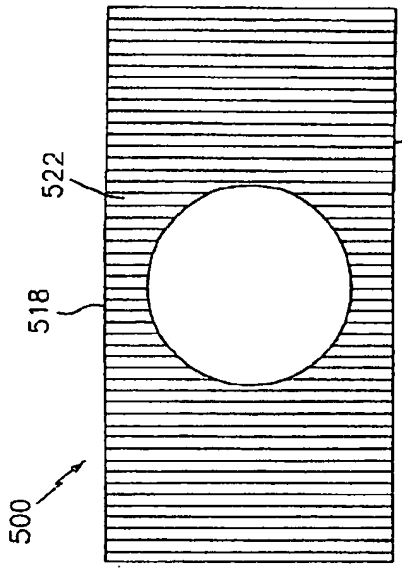


FIG. 17

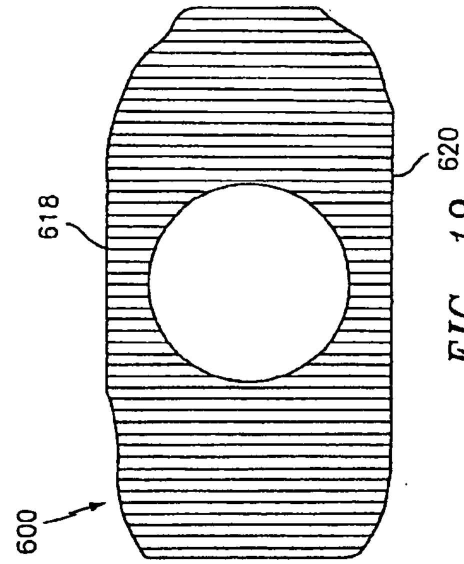


FIG. 19

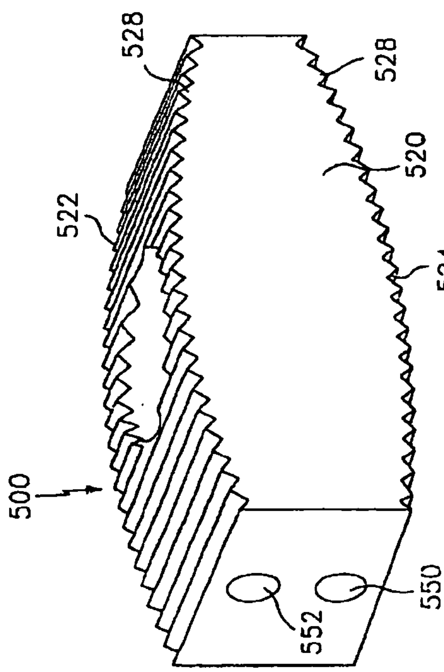


FIG. 16

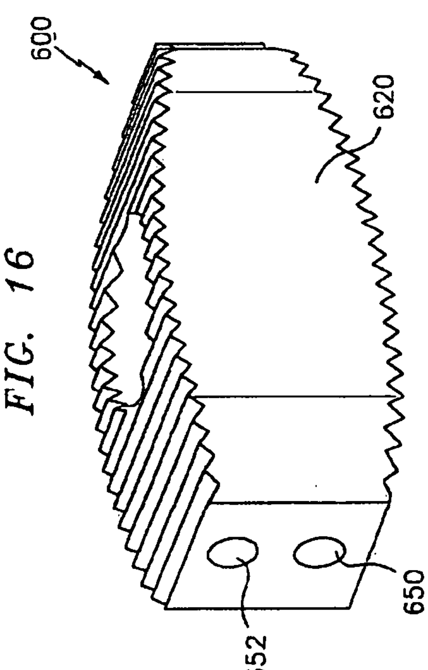


FIG. 18

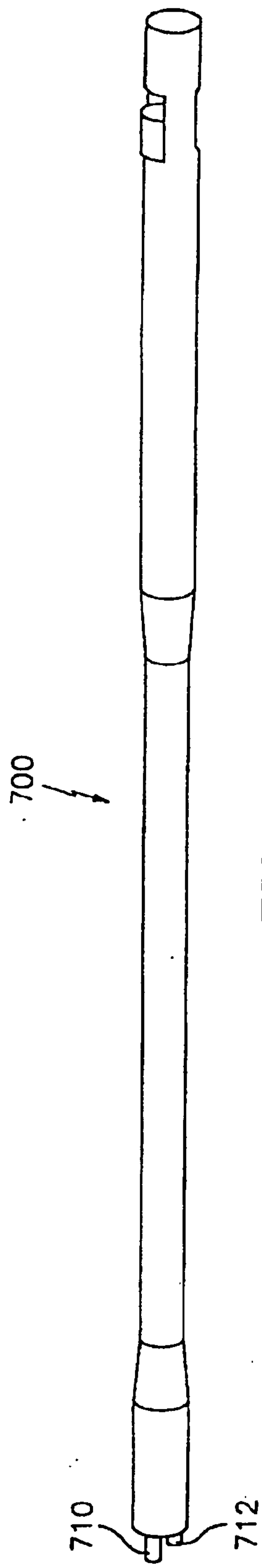


FIG. 20

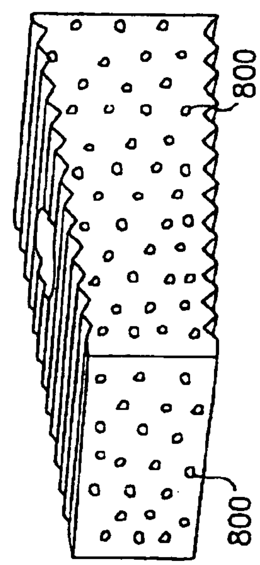


FIG. 21

RAMP-SHAPED INTERVERTEBRAL IMPLANT

BACKGROUND OF THE INVENTION

1. Technical Field

The present disclosure relates generally to intervertebral implants for spinal fusion and, more particularly, to a ramp-shaped intervertebral implant having a top surface and a bottom surface and at least one opening extending between the top and bottom surfaces.

2. Background of Related Art

Surgical procedures for fusing adjacent vertebrae together to treat back pain in patients with ruptured or degenerated intervertebral discs, spondylolisthesis or other pathologies are well known. Typically during such a procedure, a spinal implant is placed into the intervertebral space in a position to engage adjoining vertebrae. The implant is constructed from a biocompatible material which is adapted to fuse with the adjacent vertebrae to maintain proper spacing and lordosis between the adjacent vertebrae, i.e., maintain the disc space.

A variety of different types of intervertebral implants have been developed to perform this function including spinal fusion cages, threaded bone dowels and stepped bone dowels. Exemplary implants are disclosed in U.S. Patent Applications filed on even date herewith, under Certificate of Express Mail Label Nos. EL260888080US and EL071686220US, and entitled "Intervertebral Implant" and "Keyed Intervertebral Dowel", respectively, the entire disclosures of which are incorporated herein by reference.

One type of intervertebral implant has a wedge configuration. U.S. Pat. No. 5,425,772 to Brantigan discloses a wedge-shaped implant having an anterior end, a posterior end, front and rear walls, top and bottom walls and sidewalls. The implant is constructed from biocompatible carbon reinforced polymer or alternately of traditional orthopedic implant materials such as chrome cobalt, stainless steel or titanium. The top and bottom walls are tapered from the anterior end of the implant to the posterior end such that the anterior end of the implant has a height greater than the height of the posterior end of the implant. The top and bottom of the implant are continuous and unslotted and include a series of transverse teeth or serrations extending thereacross. A slot configured to receive bone graft material extends through the implant between the sidewalls.

During insertion of Brantigan's implant into the intervertebral space, the adjoining vertebrae are tensioned and a portion of disc tissue between the vertebrae is cut and removed to form channels between the vertebrae. The implant is positioned in the channel such that the teeth formed on the top and bottom surfaces of the implant engage the adjoining vertebrae. During a surgical spinal fusion procedure, two of Brantigan's implants are inserted between the adjoining vertebrae to be fused.

U.S. Pat. No. 5,443,514 to Steffee also discloses a wedge-shaped implant having upper and lower toothed surfaces, a pair of parallel side surfaces, a pair of end surfaces and a plurality of openings extending between the side surfaces. The implant is constructed from an injection molded chopped carbon fiber reinforced polymer. The openings facilitate blood flow and bone growth from one side of the implant to the other. Steffee's implant is adapted to receive an insertion tool which during insertion of the implant between adjoining vertebrae rotates the implant from a horizontal to a vertical orientation. During a surgical procedure, two of Steffee's implants are positioned between adjoining vertebrae.

Conventional wedge-shaped intervertebral implants, including those described above, have several drawbacks. For example, although autograft wedges are known, e.g., iliac crest wedges, typically, conventional wedge-shaped implants are constructed from materials which do not remodel but rather remain in place forever or until removal is necessitated, i.e., at least some or all of the implant is not replaced by new bone, but rather the implant itself is incorporated into the body. Since the implants usually become adherent to the adjoining vertebrae, if removal of the implant is ever necessitated, the procedure to effect removal is complicated and dangerous to the patient. Moreover, in conventional wedge-shaped implants, the opening(s) to facilitate bone ingrowth extend transversely through the implant and as such do not open in communication with the adjoining vertebrae. Thus, bone ingrowth and eventual fusion will occur more slowly.

Accordingly, a need exists for an improved wedge-shaped intervertebral implant which can be easily manufactured from a material which will be remodeled within the body and will more quickly become adherent to adjoining vertebrae.

SUMMARY

In accordance with the present disclosure, a ramp-shaped intervertebral implant which is constructed from animal or human cadaveric bone or bone composites, or from any biocompatible material having the requisite strength requirements suitable for implantation, is provided. The ramp-shaped implant includes a body having a first side, a second side and upper and lower surfaces. An opening extends through a central portion of the body between the upper and lower surfaces and a series of ridges are formed over at least a portion of at least one of the upper and lower surfaces. The implant decreases in height from the first end of the implant to the second end of the implant.

In a preferred embodiment, the implant is formed from the diaphysis or metaphysis of a long bone. More particularly, the implant is formed by first cutting a cortical ring from a long bone. Next, the cortical ring is secured within a holding fixture and the sidewalls of the cortical ring are machined to provide the implant with a desired shape. As such, the implant may retain its natural configuration or some or all of the sidewalls can be machined to form the implant to any configuration including rectangular, circular, C-shaped, etc. The intramedullary canal of the cortical ring defines an opening which extends from the top surface to the bottom surface of the implant. The implant is then placed in a second holding fixture and the top surface is machined to provide the appropriate taper and the ridges. These steps can be performed simultaneously using, for example, a three-dimensional computer operated milling machine. Alternately, the steps can be performed consecutively. Next, the implant is repositioned in the holding fixture and the bottom surface of the implant is machined to provide the appropriate taper and the ridges. The side surfaces may also be machined to vary the width of the implant along the longitudinal axis of the implant. A C-shaped implant can be formed by making a cut across the medial lateral plane of the cortical ring to expose the intramedullary canal. Thereafter, a ramp or taper can be provided in the anterior/posterior plane. Because the implant is constructed of bone, after insertion into the body of a patient, the implant will remodel within the body. New bone of a patient will eventually

replace some or all of the implant. Thus, if removal of the implant is ever necessitated, the implanted bone and/or the remodeled bone can be easily reamed out. Moreover, since the opening extends between the top and bottom surfaces of the implant, bone growth material which is packed into the opening directly contacts the adjoining vertebrae. Thus, fusion of the implant and adjoining vertebrae will occur more quickly.

Alternately, the ramp-shaped intervertebral implant can be formed from any biocompatible material having the requisite strength requirements via any known process including but not limited to molding and machining.

BRIEF DESCRIPTION OF THE DRAWINGS

Various preferred embodiments are described herein with reference to the drawings wherein:

FIG. 1 is a perspective view of one embodiment of the presently disclosed ramp-shaped intervertebral implant;

FIG. 2 is a top view of the ramp-shaped intervertebral implant shown in FIG. 1;

FIG. 3 is a side view of the ramp-shaped intervertebral implant shown in FIG. 1;

FIG. 4 is a front view of the ramp-shaped intervertebral implant shown in FIG. 1;

FIG. 5 is a side view of a long bone with cut lines for cutting the cortical ring;

FIG. 6 is a perspective view of a cortical ring cut from the long bone shown in FIG. 5;

FIG. 7 is a perspective view of the cortical ring shown in FIG. 6 after the sidewalls have been machined;

FIG. 8 is a side view of the cortical ring shown in FIG. 6 after the sidewalls and the top surfaces have been machined;

FIG. 9 is a side view of the cortical ring shown in FIG. 6 after the sidewalls, the top surface and the bottom surface have been machined;

FIG. 10 is a perspective view of another embodiment of the ramp-shaped intervertebral implant;

FIG. 11 is a perspective view of yet another embodiment of the ramp-shaped intervertebral implant;

FIG. 12 is a perspective view of yet another embodiment of the ramp-shaped intervertebral implant;

FIG. 13 is a perspective view of yet another embodiment of the ramp-shaped intervertebral implant;

FIG. 14 is a top view of the intervertebral implant shown in FIG. 13;

FIG. 15 is a side view of the intervertebral implant shown in FIG. 13;

FIG. 16 is a perspective view of another embodiment of the ramp-shaped intervertebral implant;

FIG. 17 is a top view of the ramp-shaped intervertebral implant shown in FIG. 16;

FIG. 18 is a perspective view of another embodiment of the ramp-shaped intervertebral implant;

FIG. 19 is a top view of the intervertebral implant shown in FIG. 18;

FIG. 20 is a side view of an implant insertion tool; and

FIG. 21 is a perspective view of another embodiment of the ramp-shaped intervertebral implant.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Preferred embodiments of the presently disclosed ramp-shaped intervertebral implant will now be described in detail with reference to the drawings, in which like reference numerals designate identical or corresponding elements in each of the several views.

FIGS. 1–4 illustrate one preferred embodiment of the presently disclosed ramp-shaped intervertebral implant shown generally as **10**. Ramp-shaped implant **10** includes a body **12** having a first wall **14**, a second wall **16**, a pair of sidewalls **18** and **20**, an upper surface **22** and a lower surface **24**. An opening **26** extends through body **12** from the upper surface **22** to the lower surface **24**. Opening **26** opens onto upper and lower surfaces **22** and **24** and is dimensioned to receive bone growth material including bone particles and/or a biocompatible osteoinductive or osteoconductive material.

Upper and lower surfaces **22** and **24** of body **12** converge from first wall **14** to second wall **16** and are configured to engage vertebral end plates after implantation. A series of ridges **28** are positioned on at least a portion of upper and lower surfaces **22** and **24**. Ridges **28** extend between sidewalls **18** and **20**. The apex of each ridge **28** defines a substantially right angle corner. Ridges **28** are configured to engage the adjoining vertebrae and prevent the implant from backing out of a receiving bed formed between the adjoining vertebrae. Alternately, in order to further prevent the implant from backing out of the intervertebral space, ridges **28** may be angled such that the apex of each ridge points towards second wall **16**. Moreover, protrusions other than ridges may be formed on the upper and lower surfaces of the implant, e.g., pyramid or semi-spherical protrusions.

Preferably, implant **10** is formed from cadaveric human or animal bone and/or bone composites. Such composites may include those discussed in U.S. Pat. No. 5,899,939 to Boyce et al. and in U.S. patent application Ser. No. 09/256,447 to Boyce et al., the entire disclosures of which are incorporated herein by reference. Alternately, other biocompatible materials can be used to form the implant. For example, surgical stainless steel, titanium, ceramic hydroxyopatite, polymers, carbon fiber, tantalum, etc., can also be used to construct the implant. Moreover, depending on the particular material used to construct the implant, a variety of different manufacturing procedures can be used to form the implant including machining and molding for example.

Referring to FIGS. 5–9, in a preferred embodiment, the implant is formed from the cortical ring of a long bone, such as the fibula, radius, ulna, humerus, tibia or femur, by first making a pair of transverse cuts A and B across the diaphysis or metaphysis of a long bone C to form a cortical ring D. Typically, larger bone including humerus, tibia and femur are used to form implants for thoracic and lumbar spinal fusion procedures, whereas smaller bones including the ulna, radius and fibula are used to form implants for cervical spinal fusion procedures. Next, cortical ring D is secured within a holding fixture (not shown) and the sidewalls of the cortical ring are machined to provide a substantially rectangular implant E. Alternately, the sidewalls of the implant can be left to their natural configuration or the sidewalls can be machined to form an implant having a variety of other configurations, e.g., circular, triangular, etc. Subsequently, implant E is secured in a second holding fixture (not shown) and upper surface **22** is machined using a computer controlled three-dimensional milling machine to form ridges **28** and to angle the upper surface **22** from first end **14** to second end **16**, i.e., provide the taper. The angle is chosen to maintain the natural curvature of the spine. Alternately, a manually operated milling tool can be used to taper upper surface **22** and subsequently form ridges **28**. Next, implant E is repositioned in the second holding fixture and lower surface **24** is machined to form ridges **26** and to angle lower

surface **24** from first end **14** to second end **16**. The intramedullary canal of the cortical ring defines opening **26**. Alternately, the taper and ridges may be provided on only one of the upper and lower surfaces of the implant.

Typically, for thoracic and lumbar spinal fusion procedures, the implant has a length of from about 20 mm to about 21 mm, a width of from about 15 mm to about 18 mm, a rear end height of from about 9 mm to about 13 mm and a forward end height from about 11 mm to about 15 mm. For cervical spinal fusion procedures the implant has a length of from about 10 mm to about 15 mm, a width of from about 10 mm to about 15 mm, a rear end height of from about 6 mm to about 10 mm and a forward end height from about 8 mm to about 12 mm. Alternately, the dimensions of the implant may be varied to accommodate the particular procedure to be performed.

Preferably, before long bone D is cut, the bone is partially demineralized by placing the long bone in a 0.6NHCL solution. By demineralizing the bone in this fashion, only the walls of the intramedullary canal and the circumferential surfaces of the bone will be demineralized. The strength imparting surfaces of the ramp implant will not be compromised. Moreover, the bone may be treated using a variety of bone healing enhancing technologies. For example, bone growth factors may be infused into the natural porosity of the bone and/or the bone may be infused with acid to further demineralize the internal matrix of the bone. Both these bone treatments may be performed using the pressure flow system disclosed in U.S. Pat. No. 5,846,484 which is incorporated herein by reference.

FIGS. **10–12** illustrate alternate embodiments of the ramp-shaped bone intervertebral implant. FIG. **10** illustrates a substantially cylindrical ramp-shaped implant, shown generally as **100**. Implant **100** may be formed by machining the sidewall of a cortical ring (FIG. **6**) to provide a substantially cylindrical configuration. Alternately, the cortical ring need not be machined but rather, it may retain its natural shape, which depending upon the bone, may vary in shape from cylindrical to triangular in configuration. Implant **110** includes ridges **128** formed on its upper and lower surfaces. The upper and lower surfaces are also machined to taper the implant along its longitudinal axis from the first end **114** of the implant to the second end **116** of the implant.

In an alternate embodiment shown generally as **200** in FIG. **11**, the implant is tapered and ridges **228** are formed on only one of the upper and lower surfaces. The other surface **224** remains flat.

In another alternate embodiment shown generally as **300** in FIG. **12**, a portion of implant **200** is removed to form a substantially C-shaped ramp implant. C-shaped implant **300** includes an opening **326** and may include protrusions, such as ridges **328**, on either or both of the upper and lower surfaces of the implant. C-shaped implant **300** may form any portion of an arc from about 60° C. to 360°.

FIGS. **13–15** illustrate another alternate embodiment of the intervertebral implant shown generally as **400**. Intervertebral implant **400** is similar to implant **10** in all respects, except that sidewalls **418** and **420** are also angled to converge toward each other from first wall **414** to second wall **416** along the longitudinal axis of the implant. Implant **400** also includes a slot **450** which communicates with a threaded bore **452**. Slot **450** and threaded bore **452** are configured to mate with an implant insertion tool (not shown). Such a slot and threaded bore may be formed on each of the implants discussed above to facilitate insertion of the implant into the intervertebral space.

FIGS. **16–19** illustrate additional alternate embodiments of the ramp-shaped intervertebral implant. FIGS. **16** and **17** illustrate ramp-shaped intervertebral implant **500**. Implant **500** is substantially rectangular in shape as viewed from above (FIG. **17**). However, the upper and lower surfaces **522** and **524** are convex and include a series of ridges **528**. Intervertebral implant **600**, illustrated in FIGS. **18** and **19**, is substantially identical to implant **500**, except that sidewalls **618** and **620** have not been completely flattened as have sidewalls **518** and **520**.

Both intervertebral implants **500** and **600** include a first wall **514, 614** having a threaded hole **550, 650** and a pilot or threaded hole **552, 652**. The holes are configured to engage a threaded prong **710** and a non-threaded prong **712** of an insertion tool **700** (see FIG. **20**). Insertion tool **700** facilitates insertion of the implant into the intervertebral space. The spacing of the pilot hole and the threaded hole may be varied on different implants such that only the proper insertion tool can be used to insert an implant into the intervertebral space. This will prevent inadvertent use of the wrong insertion tool with a particular implant. For example, this will prevent the use of instruments designed for inserting implants anteriorly with implants designed to be inserted posteriorly.

It will be understood that various modifications may be made to the embodiments disclosed herein. For example, rather than ridges, other protrusions may be formed on the upper and lower surfaces of the implant to retain the implant in a receiving bed formed between adjoining vertebrae. For example, the upper and lower surfaces may be knurled or include dimples or a variety of differently shaped projections. Moreover, any of the implants described above may include perforations **800** along any of its surfaces configured to receive bone growth material. See FIG. **21** for example. Further, the implant can be made using other known methods not disclosed in detail above, including molding and other machining processes. Therefore, the above description should not be construed as limiting, but merely as exemplifications of preferred embodiments. Those skilled in the art will envision other modifications within the scope and spirt of the claims appended hereto.

What is claimed is:

1. A ramp-shaped intervertebral implant comprising:

a body isolated from along bone having a first end, a second end and top and bottom surfaces, at least one of the top and bottom surfaces being tapered and converging towards the second end of the body, at least one of the top and bottom surfaces having a plurality of protrusions thereon, the protrusions defining substantially V-shaped elongated, parallel grooves, and at least one opening extending through the body having one end opening onto the top surface and one end opening onto the bottom surface, wherein the first end of the implant includes a threaded hole and a non-threaded hole, the holes being dimensioned to engage an insertion tool.

2. A ramp-shaped intervertebral implant according to claim **1**, wherein the protrusions include a series of ridges.

3. A ramp-shaped intervertebral implant according to claim **2**, wherein the implant includes a pair of substantially parallel side walls, each ridge of the series of ridges having a longitudinal axis that extends in a direction substantially perpendicular to the side walls.

4. A ramp-shaped intervertebral implant according to claim **1**, wherein the implant is constructed from the diaphysis or metaphysis of a long bone and the intramedullary canal of the long bone defines the bore.

5. A ramp-shaped intervertebral implant according to claim **1**, wherein the implant is formed from bone which is at least partially demineralized.

6. A ramp-shaped intervertebral implant according to claim 1, wherein the implant has a substantially rectangular configuration.

7. A ramp-shaped intervertebral implant according to claim 1, wherein protrusions are formed on both the top and bottom surfaces.

8. A ramp-shaped intervertebral implant according to claim 1, wherein at least one of the top and bottom surfaces is convex.

9. A method for forming a ramp-shaped implant comprising the following steps:

a) making a transverse cut across a long bone having an intramedullary canal to form a cortical ring;

b) machining at least one of top and bottom surfaces of the cortical ring such that the top and bottom surfaces of the cortical ring converge towards one another in a direction towards a second end of the cortical ring, at least one of the top and bottom surfaces having a plurality of substantially V-shaped elongated, parallel grooves, the intramedullary canal of the long bone defining an opening having one end opening onto the top surface of the cortical ring and having a second end opening onto the bottom surface of the cortical ring;

c) machining at least one of the top and bottom surfaces of the cortical ring to form a plurality of protrusions thereon; and;

d) forming a threaded hole and a non-threaded hole in a first end of the implant, the threaded hole and non-threaded hole being dimensional to engage an insertion tool.

10. A method for forming a ramp-shaped implant according to claim 9, wherein the protrusions include a series of ridges.

11. A method for forming a ramp-shaped implant according to claim 10, wherein the machining steps further include use of a three-dimensional milling machine.

12. A method for forming a ramp-shaped implant according to claim 11, wherein steps c) and d) are performed simultaneously using the three-dimensional milling machine.

13. A method for forming a ramp-shaped implant according to claim 9, further including the step of partially demineralizing the bone.

14. A method for forming a ramp-shaped implant according to claim 13, wherein the step of partially demineralizing the bone occurs before the cortical ring is cut from the long bone.

15. A method for forming a ramp-shaped implant according to claim 9, further including the step of:

d) machining sidewalls of the cortical ring to form an implant having a substantially rectangular configuration.

16. A method for forming a ramp-shaped implant according to claim 9, further including the step of:

d) infusing bone growth material into the bone.

17. A method of forming a ramp-shaped implant according to claim 9, further including the step of:

d) forming a plurality of perforations in surfaces of the implant other than the top and bottom surfaces.

18. A method of forming a ramp-shaped implant according to claim 9, wherein at least one of the top and bottom surfaces is convex.

19. A method for forming a ramp-shaped implant comprising the following steps:

a) making a transverse cut across a long bone to form a cortical ring;

b) machining at least one of the top and bottom surfaces of the cortical ring to taper the cortical ring from a first end of the cortical ring to a second end of the cortical ring and to provide a plurality of substantially V-shaped elongated, parallel grooves, the intramedullary canal of the long bone defining an opening having one end opening onto the top surface of the cortical ring and having a second end opening onto the bottom surface of the cortical ring;

c) machining at least one of the top and bottom surfaces of the cortical ring to form a plurality of protrusions thereon; and

d) infusing bone growth material into the bone.

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